12.

EXPLANATORY TEXT

TO

WOOD'S OPHTHALMIC TEST-TYPES

AND

COLOR-BLINDNESS TESTS

BY

G. R. CUTTER, M.D.,

Surgeon New York Eye and Ear Infirmary; Ophthalmic and Aural Surgeon St. Catherine's and Williamsburgh Hospitals, etc., etc.

NEW YORK
WILLIAM WOOD & COMPANY
27 GREAT JONES STREET
1880

PREFACE.

The accompanying test-types are intended to afford the physician a means of testing the acuteness of vision with exactness, to record the result of his examinations in such a manner as to be of easy subsequent reference, and to be intelligible to others.

It is often necessary for the general practitioner to ascertain the refraction of a patient. A set of trial glasses has therefore been added.

The subject of color-blindness is assuming a practical form, and we are all concerned in the dangers arising from it on land and sea. The detection and elimination of the color-blind is important in connection with railroad and marine signals. Holmgren's worsted test has been selected as the one best adapted to this purpose.

The accompanying instructions, necessarily brief, are not intended to replace a text-book, of which so many excellent ones have lately appeared, but merely to serve as a résumé of what is important in forming a diagnosis, and to enable the family physician to decide whether his patient requires the special services of an oculist.

G. R. CUTTER, M.D.

312 Second Avenue, N. Y., June, 1880.

EXPLANATORY TEXT.

THE TEST-TYPES.

VARIOUS test-types are used in the examination of the acuteness of vision. Those of Snellen and Jaeger have received universal acceptation, and in nearly all clinical reports we find the vision recorded by either the former or the latter system.

Snellen's letters are square, and their size increases in a definite ratio, so that each number is seen at an angle of five minutes. Many persons experience difficulty in reading these square letters with fluency. The letters of the ordinary type to which they have been accustomed are of unequal thickness, and differ both in dimension and definition. Jaeger's test-types are composed of letters such as are ordinarily used in printing, and are, therefore, generally used for ascertaining the fluency with which small print can be read; and those of Snellen, for testing and recording with accuracy the acuteness of vision.

The principles on which Snellen constructed his test-types are thus stated by him:

1. The smallest angle, at which objects of known size and known form can be distinguished, determines the degree of the acuteness of vision. The size of the image formed on the retina depends on this angle, and the distinguishing power increases with the growth of this image.

2. To determine the smallest visual angle we measure the utmost distance at which objects of definite size can be recognized.

3. A visual angle and corresponding distance being taken as unit of measure, the proportion between such distance and that at which the object is actually seen, expresses the acuteness of vision.

4. We take as unit for comparison the recognition of letters seen at an angle of 5 minutes. We have adopted as proper objects square letters, the limbs of which have a diameter equal to one-fifth of the letter's height. Such letters are clearly distinguished by a normal eye at an angle of 5 minutes; as the limbs and subdivisions of the letter just measure $\frac{1}{5}$ of their height, they present themselves at an angle of 1 minute. In testing accuracy of vision, we accept perfect recognition and not uncertain perception of letters.

5. The numbers placed above each type express, in metres, the distance at which the letters are seen at our standard angle of 5 minutes.

6. The utmost distance at which the types are recognized (d), divided by the distance at which they appear at an angle of 5 minutes (D), gives the formula for the acuteness of vision (V); $V=\frac{d}{\text{D}}$.

If d and D be found equal, and D$=$6 be thus recognized at a distance of 6 metres, then $V=\frac{6}{6}=1$; in other words, there is normal acuteness of vision. If, on the contrary, d be less than D, and if D$=$6 be only visible within 3 metres, or D$=$3 within 1 metre, these two cases are thus respectively expressed: $V=\frac{3}{6}=\frac{1}{2}$, $V=\frac{1}{3}$.

But d may be greater than D, and D$=$6 be visible at a greater dis-

tance than 6 metres; in such case the acuteness of vision is greater than the normal average.

7. The normal acuteness of vision decreases with age. This is caused, partly, by decreased transparency of the media of the eye, which lessens the perfection of the retinal image; partly by decreased perceptive and conductive power of the nervous structures.

8. The value of *V* should be found equal in testing with the different types, each at its corresponding distance. If such is not the case, and *V* appears to diminish considerably within or beyond a certain distance, it may be inferred that the refraction is in fault, or that the eye is not adjusted for such distance. In case of diminished acuteness of vision, *V* must still—within the limits of adjustment—be equal for different numbers of types, each at its own distance; if, therefore, *e. g.*, at 6 metres *V*, is proved to be $=\frac{6}{36}=\frac{1}{6}$, then at 3 metres *V* cannot differ considerably from $\frac{3}{18}=\frac{1}{6}$. In case any other value for *V* were stated, it would imply carelessness, exaggeration, dissembling, or simulation.

9. Acuteness of vision being found considerably greater for near than for distant objects, myopia may be assumed to exist. The farthest point of clear sight (the farthest distance at which *V* is at a maximum) expresses approximatively the degree of the myopia. A person, *e. g.*, seeing clearly only within a distance of half a metre, may have a myopia of 2 dioptrics, (see page 9) and consequently require glasses of -2 D to make his vision of distant objects equal to that of near ones. Myopic persons generally state the farthest point of clear sight as rather too near, in consequence of the convergence of the visual axes preventing the total relaxation of accommodation. Only in case of paralysis of the accommodation the farthest point of clear sight in myopia of *e. g.* 2 D reaches half a metre.

10. If the distinctness of distant objects increases with positive glasses, hypermetropia is proved to be present, and the strongest glass with which *V* still improves, or at least remains unaltered, determines the degree of manifest hypermetropia. Hypermetropic persons cannot thoroughly relax their accommodation when looking at distant objects, and their manifest hypermetropia is but a part of the total. The difference between manifest and total hypermetropia depends on the amount of accommodation, which decreases as age increases.

11. Should the horizontal and vertical strokes not be discerned with equal clearness, the focus of the eye is not the same for the horizontal and vertical meridians. The cylindrical glass which equalizes such difference shows the degree of astigmatism.

12. Positive lenses magnify, negative lenses diminish the size of the retinal image. This magnifying and diminishing effect increases with the power of the lenses, and especially with the distance at which they are applied from the eye.

Myopic persons, armed with appropriate negative lenses, necessarily show a diminution of *V;* on the contrary, hypermetropic persons, armed with appropriate positive lenses, show a relative increase of *V.*

13. The size of the pupil is not without its influence upon the value of *V.* If the light be insufficient, *V* increases in proportion to the dilatation of the pupil; contraction of the pupil, on the contrary, increases

the amount of *V*, where the retinal image is confused (from imperfect adjustment of the eye, or from irregular refraction of the media).

The pupil diminishes in size in accommodating for near objects, and increases with adjustment for distant objects; this may occasion some trifling difference in the amount of *V* assigned for the several distances.

14. The amount of *V* is dependent on the intensity of light. Insufficient intensity, but also too great intensity of light, lessens *V*. The most favorable amount of light is variable, and depends especially upon the degree of light to which the eye has been exposed immediately before.

Independently of the strength of light, *V* is influenced moreover by the contrast between the white and black of the letters. The contrast as well as the illumination of the letters is, therefore, required to be of constant value during our experiments.

15. The recognition of our isolated letters is a better test of *V* than reading a line of words in the corresponding types. For, in reading, some familiar words may be regarded as equivalent to letters of a larger size; while the individual letters of unfamiliar words may be less distinguishable, from their close apposition as usually printed.

In reading tests, fluency is chiefly to be regarded; a limited or interrupted field of vision makes reading less fluent.

16. Square figures, constructed in the proportion of one to five, may be considered equal to our test-types. For people who cannot read, there are added to the test-types square figures, the form of which can be promptly described.

17. A white object on a black ground looks larger than a black object of the same size on a white ground.

DIRECTIONS FOR USING THE TEST-TYPES.

The large card, No. 1 (or No. 2, if the person to be examined does not know how to read), having been placed in a good light, the person whose vision is to be tested is brought to a position six metres (about 20 feet) distant from the card.

Each eye should be tested separately (a card being held before the eye not tested, so as to exclude it from vision, without closing it or making pressure upon it) and the vision noted.

Thus, if D=6 is read with the right eye, R.E., $V=\frac{6}{6}$, if D=24, $V=\frac{6}{24}$. If D=60 can only be read at a distance of three metres, then $V=\frac{3}{60}$. By thus stating the fraction unreduced, the distance at which the test was seen can be readily ascertained from the record. After stating the vision of each eye separately, the combined vision should also be ascertained and noted.

Having ascertained the vision for distance, we then test the near vision by means of the smaller type. Snellen's smallest type (D=0.5) should normally be read at the distance of half a metre, and that marked D=1 at one metre. The near vision is recorded as: *V*=Snellen D= (the size of the type) at (the farthest distance at which it can be read).

The "*accommodation*" means the power which every normal eye possesses of adjusting itself for different distances. It is tested by ascertaining the nearest point (punctum proximum, or *p*), and the farthest (punctum

remotum, or *r*) of distinct vision for the smallest readable type. When there is no error of refraction, the eye is said to be emmetropic.

If HYPERMETROPIA or far-sightedness is suspected, convex glasses should be tried, using the large card as before. Should spasm of accommodation not be present, the vision will be improved by the glasses. When the vision has been improved as much as possible, or when the *strongest* glass has been found with which D=6 can be read, the *manifest* hypermetropia is ascertained. This may be thus stated: Hm= (the number of the plus glass). Supposing the glass to be a +1 D, it would be Hm=1 D. Supposing that D=6 was read with this glass, this condition would be stated thus: +1 D $V=\frac{6}{6}$.

The *absolute* hypermetropia can be ascertained only after paralyzing the accommodation with atropine or some other mydriatic. It is represented by the glass with which the examined eye best perceives the distant test. Thus, if D=6 is best seen with +1 D, this would be expressed as: Ha=1 D, and it is well to state at the same time, +1 D $V=\frac{6}{6}$.

The refraction of each eye should be noted separately. Frequently the vision is normal ($\frac{6}{6}$) both with and without a convex glass. In this case there is hypermetropia, and the strongest glass thus accepted measures the degree of manifest hypermetropia, as has already been said.

Having ascertained the amount of hypermetropia the near vision should be tried and noted. If the smallest type can be read at the proper distance with the aid of the glass corresponding to the manifest hypermetropia, a pair of spectacles, with the lenses of the same strength, may be given for constant use; but if the type cannot be seen, or can only be made out with difficulty, stronger glasses should be tried in succession until the eyes are suited. The near vision should be noted as above, giving the number of the glass with which the type was read.

If MYOPIA, or near-sightedness, is suspected, concave glasses should be tried, using the large card as before. The myopia, which corresponds to the *weakest* glass with which the best vision is obtained, is expressed as: M= (the number of the concave glass). Supposing this glass to be a −1 D, it would be: M=1 D, and if D=6 was read with this glass, the statement would be −1 D $V=\frac{6}{6}$.

When there is considerable spasm of accommodation, concave glasses will be accepted, and the vision may be improved by them, even though the eye is not myopic, but is emmetropic or even hypermetropic. If this condition be suspected, atropine should be used. After the accommodation has been paralyzed, if the eye is really myopic, a concave glass will still be needed to make the vision good as it was before using the atropine. If the apparent myopia was due to spasm of accommodation, concave glasses will be refused, and either no glass at all (in which case the eye is emmetropic), or a convex glass will be necessary, and will show the amount of absolute hypermetropia.

Having ascertained the vision for distance, the near vision should be tested, by means of the smaller type, and recorded as above.

If the vision for distance has been equally good through several different glasses, always select the weakest of them. If the myopia is less than 2 D, no spectacles should be worn. A pair of eye-glasses may be

given for occasional use for the distance. If the myopia is between 2 D and 3 D, spectacles of one strength will suffice for reading and for seeing at a distance. Should the myopia be of a higher degree, 3 D to 6 D, spectacles with weak lenses should be given for reading, and eye-glasses of greater strength for seeing at a distance. In very high degrees of myopia, beyond 6 D, glasses which completely neutralize the myopia should not, as a rule, be worn constantly, as they will often fatigue the eye, and produce too much dazzling. The spectacles which suit best for reading and render objects distinct at a distance of eight or ten feet should be given for constant use. The glasses which completely neutralize the myopia may be given in the form of eye-glasses for occasional use in walking about or where it is necessary to see at a distance.

Presbyopia, or old sight, is the result of failing accommodative power due to advanced age. It is not a defect of refraction, though it may be associated with the latter. It is a condition in which vision of near objects begins to be noticeably interfered with. In the normal eye this condition is reached soon after forty. The rate of diminution of the accommodation is so uniform, in most cases, that the glasses required may often be determined merely from the patient's ~~eye~~. Thus the glass necessary to enable the eye to read at 8 inches is :

At 45	about	1 D.	At 65	about	4.5 D.
" 50	"	2 D.	" 70	"	5.5 D.
" 55	"	3 D.	" 75	"	6 D.
" 60	"	4 D.	" 80	"	7 D.

In practice, it is unsafe to rely on age as anything more than a general guide. Allowance should also be made for any hypermetropia or myopia which may be present, and it is always proper to examine the eye for these conditions.

The presbyopia is measured by the weakest convex glass with which the finer letters can be read with facility at their proper distance from the eye. It is noted as Pr. = (the number of the convex glass).

If astigmatism, or a difference in the refraction of different meridians of the eye, is suspected, the large card No. 7 should be hung up in a good light, 6 metres from the person to be examined.

It will be noticed that this card contains groups of three lines drawn in different directions. The six upper groups, constituting one series, are coarser than those below them, which form another series. If the lines of one group are seen with greater distinctness, that is, appear to be more sharply cut than the lines of any other group in the same series, astigmatism is present, and is noted as As.

The accommodation exerts a very disturbing influence in measuring astigmatism, hence it is usually necessary to paralyze the former before attempting to measure the latter.

There are two varieties of astigmatism, the *irregular* and the *regular*. The former is seldom much benefited by glasses.

Donders, the acknowledged authority on this subject, has distinguished three forms of *regular* astigmatism : I. Simple astigmatism; II. Compound astigmatism; III. Mixed astigmatism.

In simple astigmatism the state of the refraction of the one principal meridian is emmetropic, and that of the other is either myopic or hypermetropic. Simple astigmatism is divided into: 1, simple myopic astigmatism, in which myopia exists in the one principal meridian, and emmetropia in the other. It is noted as Am; 2, simple hypermetropic astigmatism, in which there is hypermetropia in the one principal meridian and emmetropia in the other. It is noted as Ah.

In compound astigmatism myopia or hypermetropia exists in both principal meridians, but the degree varies. There are also two forms of this variety: 1, compound myopic astigmatism (noted as M+Am), the degree of myopia varying in the two principal meridians; 2, compound hypermetropic astigmatism (noted as H+Ah), the degree of hypermetropia varying in the two principal meridians.

Mixed astigmatism, in which the one principal meridian is myopic and the other hypermetropic, is a rare form. Two varieties have been distinguished: 1, mixed astigmatism with predominant myopia (noted as Amh); 2, mixed astigmatism with predominant hypermetropia (noted as Ahm).

Astigmatism is of comparatively rare occurrence, and requires for its correction the aid of cylindrical lenses. The adjustment of these lenses is a matter of considerable intricacy, and should be undertaken only by those who have made it a special study. Our trial case, though it does not contain cylindrical lenses, furnishes the means for the detection of astigmatism, and an approximate estimation of its degree.

In astigmatism, as in the other cases, each eye should be examined separately. The direction of the group of lines which appears most distinct should be ascertained, and the small card with three parallel lines placed with the lines at the angle, noted. Then place the stenopaic slit in the frame in front of the eye, but at an angle perpendicular to that of the lines being tested. Then find the convex or concave glass which renders the lines most distinct. When found note the angle and the number of the glass. The lines of the small card are then to be turned 90 degrees, the stenopaic slit turned to correspond, that is at right angles to the lines, and the glass found which renders the lines distinct in their new position. When found, note the angle and the glass as before. The difference between the two glasses represents the degree of astigmatism. In making up the combination for the correction of the astigmatism, it is customary to give the stronger refraction to the spherical glass, and the weaker to the cylindrical lens. The accuracy of the combination may be tried on either of the cards which contain lines. If all the lines running in different directions appear equally distinct, the astigmatism is corrected for the distance. Before this is accomplished, however, it may be found necessary to make slight changes in the combinations.

In noting the combination put the letter s after the spherical glass, then the sign of combination $\bigcirc$, and the letter c after the cylindrical glass, with the degree of its axis, reckoned from the horizontal meridian from the left toward the right, thus: + 2 D. s. $\bigcirc$ — 1 D c, axis 90°.

After correcting the astigmatism for the distance, the near vision should be corrected with the aid of the finer lines.

THE TRIAL GLASSES.

The box contains eight glasses, numbered according to the metric system. The convex or positive glasses are designated by the plus (+) sign, the concave or negative by the minus (—) sign. Formerly the glasses were numbered by fractions, of which the numerator is always 1, and the denominator the focal distance of the glass, expressed in inches. The inch scale for numbering lenses is now giving place to the metric scale, which is much more convenient. In this scale the unit is a lens of one metre focal length, and for convenience is called a dioptric (D). A lens of double this strength, or half a metre focal length, is 2 dioptrics (2 D).

The dioptric system may be readily reduced to the old (Paris) inch system, by simply dividing 36 by the dioptric number; thus $36 \div 3 = 12$; hence 3 D $= \frac{1}{12}$ of the old system. For convenience of reference, we here give a table of the approximate equivalents of the two systems.

Dioptric.	Old system.	Dioptric.	Old system.	Dioptric.	Old system.
.5	$\frac{1}{72}$	3.	$\frac{1}{12}$	5.5	$\frac{1}{6\frac{3}{4}}$
1.	$\frac{1}{36}$	3.5	$\frac{1}{11}$	6.	$\frac{1}{6}$
1.5	$\frac{1}{24}$	4.	$\frac{1}{9}$	7.	$\frac{1}{5}$
2.	$\frac{1}{18}$	4.5	$\frac{1}{8}$	8.	$\frac{1}{4\frac{1}{2}}$
2.5	$\frac{1}{15}$	5.	$\frac{1}{7}$	9.	$\frac{1}{4}$

Our case contains
+ .5 1. 3. 5.
— .5 1. 3. 5.

With these, every desirable combination may be made by placing one or more of them in front of each other in the grooved holder, as is shown in the following

Table of Combinations.

Dioptric.	Convex.	Concave.	Dioptric.	Convex.	Concave.
.5	+ .5	— .5	5.	+5.	—5.
1.	+1.	—1.	5.5	+5. + .5	—5. — .5
1.5	+1. + .5	—1. — .5	6.	+5. +1.	—5. —1.
2.	+5. —3.	—5. +3.	6.5	+5. +1. + .5	—5. —1. — .5
2.5	+3. — .5	—3. + .5	7.	+5. +3. —1.	—5. —3. +1.
3.	+3.	—3.	7.5	+5. +3. — .5	—5. —3. + .5
3.5	+3. + .5	—3. — .5	8.	+5. +3.	—5. —3.
4.	+5. —1.	—5. +1.	8.5	+5. +3. + .5	—5. —3. — .5
4.5	+5. — .5	—5. + .5	9.	+5. +3. +1.	—5. —3. —1.

COLOR-BLINDNESS.

Among the many scientists who have made this subject a special study, Professor Frithiof Holmgren of Upsala, Sweden, is generally acknowledged to occupy the most prominent position, and his method of testing for color-blindness is the one usually adopted.

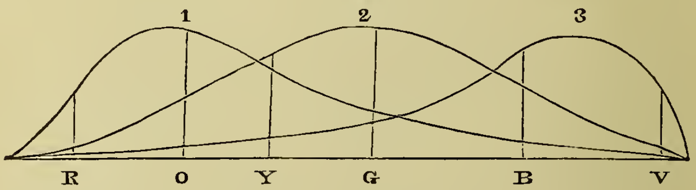
The following explanations and directions for using the test are taken from his various articles in the Swedish journals, and from his book on "Color-blindness in its relations to railroads and the marine."

His system is based on the Young-Helmholtz theory of color sense. Helmholtz, in his "Physiologischen Optik," says: "A reduction of colors to three base colors has only a subjective meaning; it is but reducing or carrying back the sensations of color to three base or final sensations. In this view Thomas Young correctly grasped the problem, and, in fact, his theory gives us a very simple and clear view and explanation of all the phenomena of the physiology of color. Thomas Young holds that—

1. There are in the eye three kinds of nerve-fibres. Stimulation of the first produces the sensation of red, the second that of green, and of the third the sensation of violet.

2. Objective homogeneous light excites these three kinds of fibres in varying degree according to the wave-lengths. The red perceptive fibres will be strongest stimulated by light of the greatest wave-length, the green perceptive by light of medium wave-length, and the violet perceptive by light of the smallest wave-length. Here must not be excluded, but rather accepted in explanation of a series of phenomena, that each spectral color excites all three kinds of fibres, but one less, the others more strongly. Let us suppose, as in Fig. 1, the spectral colors in a hori-

Fig. 1.



zontal row from red to violet; then the three curves will represent the intensity of stimulation of the three kinds of fibres: 1, the red perceptive; 2, the green perceptive; 3, the violet perceptive elements or fibres.

Simple *red* strongly stimulates the red perceptive, less the other two: sensation, *red*.

Simple *yellow* stimulates moderately the red and green perceptive, feebly the violet: sensation, *yellow*.

Simple *green* stimulates strongly the green perceptive, much less the other two: sensation, *green*.

Simple *blue* stimulates moderately the green and violet perceptive fibres, feebly the red: sensation, *blue*.

Simple *violet* stimulates strongly the violet perceptive, feebly the other fibres: sensation, *violet*.

Equally strong stimulation of all the fibres gives the sensation of white or whitish colors.

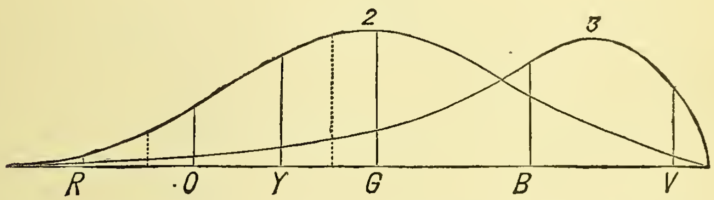
In applying this principle to color-blindness Holmgren says: to explain the abnormal sense of colors by the theory of the normal, we can, in advance, conceive various possibilities. Let us suppose that one of the three fundamental perceptions is wanting, or that one of the primi-

tive colors is absent; it is clear that the whole chromatic system will be upset. It is evident, therefore, that this system must be completely different, according to the absence of one or the other of the three primitive colors. It is virtually just in this way that it has been attempted to explain cases of a strongly marked defect in the chromatic sense, or genuine types of blindness to color found in real life. The term color-blindness has been justified by this, as it indicates in each case a genuine blindness to one of the primary colors. In this way, therefore, we distinguish, according to the kind of element wanting, three classes of blindness:

1st. Red-blindness.
2d. Green-blindness.
3d. Violet-blindness.

1. According to the theory, blindness to *red* is due to the absence or paralysis of the organs perceiving red (Fig. 2). Red-blindness has, then,

FIG. 2.



but two fundamental colors, which, adhering strictly to the theory, are *green* and *violet*. The curves distinctly show what aspect the various kinds of lights of the spectrum must have for the chromatic sense, such as the one we have in view.

Spectral red, which feebly excites the perceptive organs of green, and scarcely at all those of violet, must consequently appear to the red blind a *saturated green of a feeble intensity*, more saturated than normal green, into which a sensible portion of the other primitive colors enters. Feebly luminous red, which affects the perceptive organs of red in a normal eye sufficiently, does not, on the other hand, sufficiently excite the perceptive organs of green in the red-blind; and it therefore seems to them black. Spectral *yellow* seems to them a *green saturated and intensely luminous;* and, as it constitutes the precisely saturated and very intense shade of that color, it can be understood how the red-blind select the name of that color, and call all those tints that are, properly speaking, green, *yellow*. *Green* shows, as compared with the preceding colors, a more sensible addition of the other primitive colors; it then appears, consequently, like a more intense but whitish shade of the same color as yellow and red. The greatest intensity of light in the spectrum, according to Seebeck's observations, does not appear to the red-blind to be in the yellow region, as it does to the normal eye, but rather in that of the blue-green. In reality, if the excitation of the perceptive organs of green, as it was necessary to assume, is strongest for green, the maximum of the total excitation of the red-blind must be found slightly toward the blue side, because the excitation of the organ perceiving violet

is then increased. The white of the red-blind is naturally a combination of their two primitive colors in a determinate proportion, a combination which appears blue-gray to the normal sight; this is why he regards as gray the spectral transition colors from green to blue. When the other color of the spectrum, which they call *blue*, preponderates, because indigo-blue, though somewhat whitish according to their chromatic sense, is to them, owing to its intensity, a more evident representative of that color than violet.

This description of the manner in which the red-blind forms a conception of the different kinds of light of the spectrum is assuredly a conclusion logically deduced from the theory; but it accords so well, at the same time, with the experience acquired in examining the color-blind, that this might perfectly serve to support and corroborate the theory. We will simply add a point for our especially practical purpose, or rather emphasize one point of this theory. In fact, it is clear that a red and a green light especially excite one and the same element in the red-blind. A rag red and green, or an object red and green, to the normal sense, must seem fundamentally to the red-blind to be the same color; and if, in especial cases, he knows how to discriminate, his judgment is simply guided by the intensity of the light. The intensity of light is much more feeble (as shown by Fig. 2) in red than in green. If, then, a red-blind individual finds that a red and a green tint are exactly alike, it is necessary that the green be to the normal eye much less intense than the red. This is distinctly shown by the vertical dotted lines between R and O, and also between Y, and G, in Fig. 2; and this is entirely confirmed by experience.

2. *Green-blindness* derives its origin, according to the theory, from the absence or paralysis of the perceptive elements of green. The green-blind has therefore but two fundamental colors: that is—still adhering closely to the theory—red and violet. The spectrum for green-blindness should be, according to the theory, constructed in the following manner :—

The spectral *red*, which strongly excites the perceptive organs of red, and but very faintly those of violet, must, therefore, appear to the green-blind as an extremely saturated red, but of a light somewhat less intense than the normal red, which is comparatively more yellowish, as green forms a part of it.

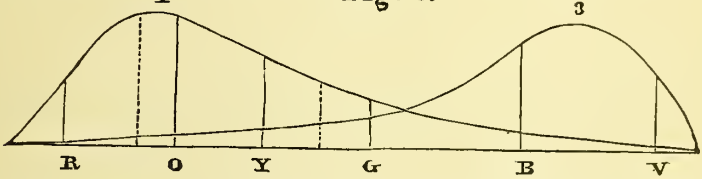
The spectral *orange* is again a very saturated red, but much more luminous. Yellow is undoubtedly a more intensely luminous red than the spectral red, but, on the other hand, more whitish, because a sensible portion of the other primitive color enters into it.

Green, with its shades inclining to yellow and blue, ought, correctly speaking, to be a saturated purple, and with a mean intensity of light; but it is the white (gray) of the green-blind; for it is composed of almost equal parts of the two primitive colors.

The *blue* is an intense violet, but a little less saturated than indigo, which is more strongly luminous and more saturated. Violet is a little less intense, but more saturated than normal violet. The tints most luminous, and at the same time most saturated, which must constitute the types of the primitive colors of the green-blind, are orange—or its imme-

diate neighbor in the spectrum, red—and indigo blue. Now, orange is a color which, in ordinary language, especially among the uncultivated and unpractised, is indiscriminately called red and yellow. This fact explains why the green-blind denominate their first primary color sometimes red and sometimes yellow. We will add to this description the same remark made about red-blindness. In green-blindness the same organ is also found affected by spectral red and green light. Red and green are then perceived by the green-blind in the same way, or, in other words, are to him in fact exactly the same color. In cases where he succeeds in distinguishing them, it is by the aid of the intensity of the light; but, with regard to this intensity of the light, it is the opposite of what occurs in the case of the red-blind. A green tint, which to the green-blind must appear exactly like a red one, to a normal sense of color must be sensibly

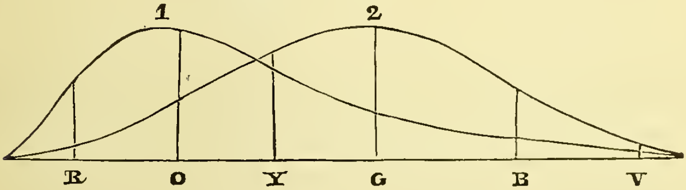
Fig. 3.



more luminous than red. This is shown by the dotted vertical lines between R and O, and also between Y and G (Fig. 3), and is confirmed in every respect by experience.

Violet-blindness (Fig. 4) is due, according to the theory, to the ab-

Fig. 4.



sence or paralysis of the elements perceiving *violet.* The two primitive colors of the violet-blind are, then, according to the theory, *red* and *green,* and it is plain that they do not confuse these colors. This kind of blindness, from the experiments made thus far, must be very rare; while the first two kinds are comparatively very common.

Those who desire a more extended knowledge of this subject are advised to read Dr. B. Joy Jeffries' book—"Color-blindness: Its dangers and its detection," Boston, 1879.

HOLMGREN'S DIRECTIONS FOR USING THE TEST.

The Berlin worsteds are placed in a pile on a large plane surface, and in broad daylight; a skein of the test-color is taken from the pile, and laid aside far enough from the others not to be confounded with them during the trial. The person to be examined is requested to select the other skeins most resembling this in color, and place them by the side

of the sample. The examiner should explain that resemblance in every respect is not necessary; that there are no two specimens exactly alike; that the only question is the resemblance of the color; and that, consequently, he must endeavor to find something similar of the same shade, something lighter and darker of the same color, etc.

The colored plate is for the purpose of assisting the examiner in the choice of his colors, and helping him decide the character of the trouble from the mistakes the color-blind make. We have attempted to represent the colors we are now to speak of. They are of two classes:

1. The *colors for samples* (*test-colors*); that is, those which the surgeon presents to the persons examined; and,

2. The "*colors of confusion;*" that is to say, those which the color-blind selects from the heap of worsteds, because he confuses them with that of the sample.

The first are horizontal on the plate, and marked with Roman numerals; the second are vertical, under the test-colors, and marked with Arabic figures.

The colored table is not intended to be directly used to test with, though it may serve this purpose occasionally. It is rather to simply assist the surgeon in his choice of the correct test-colors, and help him diagnosticate the special form of color-blindness.

As to the conformity between the worsteds the color-blind take from the heap and the confusion colors of the plate, we must simply rely on the tone, and not much on the intensity of light or degree of saturation. In all cases where we have to vary from this rule, we must hold to the relative rather than the absolute saturation. The confusion colors of our table are only to illustrate the color-blind's mistakes, and this purpose they serve perfectly.

TEST I.—The *green* sample is presented. This sample should be the palest shade (the lightest) of very pure green, which is neither a yellow-green nor a blue-green to the normal eye, but fairly intermediate between the two, or at least not verging upon yellowish green.

Rule.—The examination must continue until the one examined has placed near the sample all the other skeins of the same shade, or else, with these or separately, one or several skeins of the class corresponding to the colors of confusion (1—5), until he has sufficiently proved by his manner of doing it that he can easily and unerringly distinguish the confusion colors, or until he has given proof of unmistakable difficulty in accomplishing this task.

Diagnosis.—He who places beside the sample one of the colors of confusion (1—5)—that is to say, finds that it resembles the test-color—is *color-blind.* He who, without being quite guilty of this confusion, evinces a manifest disposition to do so, has a *feeble chromatic sense.*

Remark.—We must remember that we might have taken more than five colors for confusion; but we have here in view, not *every* kind of defective color sense, but only those important in the business of railways. The number of colors on the plate is therefore sufficient, as these are the most important and most common.

As to No. 1, which represents the gray color, we would remark that too much stress is laid on the light intensity, or on slight differences in the color tone. This is especially true of the gray skeins which the examined puts with the sample. If we need determine only whether a person was color-blind or not, no further test would be necessary. If we want to know the kind and degree of his color-blindness, then we must go on with another test.

TEST II.—A *purple* skein is shown the examined. The color should be midway between the lightest and darkest. It will only approach that given in II. of the plate, because the color of the worsted is much more brilliant and saturated, and more towards the blue.

Rule.—The trial must be continued until the one examined has placed near the sample all or the greater part of the skeins of the same shade, or else, simultaneously or separately, one or several skeins of confusion (6—9). He who confuses the colors selects either the light or deep shades of blue and violet, especially the deep (6 and 7), or the light or deep shades of one kind of green or gray inclining to blue (8 and 9).

Diagnosis.—1. He who is color-blind by the first test, and who, upon the second test, selects only purple skeins, is *incompletely color-blind.*

2. He who, in the second test, selects with purple only green and gray, or one of them, is *completely red-blind.*

3. He who, in the second test, selects with purple only green and gray, or one of them, is *completely green-blind.*

Remark.—The red-blind never selects the colors taken by the green-blind, and *vice versa.* Often the green blind places a violet or blue skein side of the green, but only the brightest shades of these colors. This does not influence our diagnosis.

The fact that many green-blind also select bright blue, in this test, besides gray and green, or one of these colors, has led to misunderstanding. Some have from this concluded that red and green blindness may exist together in the same individual; others have thought that these two kinds of color-blindness were not regularly distinguished by my method. The former conclusion is not correct. The two kinds have great similarity in close unanimity with the theory, but differ in innumerable slight variations. They are, nevertheless, in view of the theory, to be considered as two sharply-defined species.

The second conclusion can only arise from not understanding and not using the method correctly. The especial purpose of this method must here be kept constantly in view, and that is to find a characteristic of the defective color-perception of the examined. This characteristic, or sign, with green-blindness, is the confusing the purple with gray or green, or both. This confusion is the point to be determined; all else may be neglected. A complete color-blind, who confuses purple with gray or green (bluish-green), or both, is *green-blind, do* what *else he may.* This is the rule, and it will not fail the careful and observant examiner who understands the application of the test. On the contrary, it is often possible, in marked cases of incomplete color-blindness, to decide which kind we have by the way the examined acts with his hands.

We do not mean by this that the diagnosis is always very easy. Practice and knowledge are necessary. Moreover, there is a long series of degrees from incomplete color-blindness to normal vision on the one side, and, on the other, to complete color-blindness. There must naturally be a border-line where differences of the two kinds of color-blindness cease to be recognized.

The examination may end with this test, and the diagnosis be considered as perfectly settled. It is not even necessary, practically, to decide whether the color-blindness is red or green. But to be more entirely convinced of the relation of complete color-blindness with the signal colors, and especially to convince, if necessary, the railway employees and others who are not specialists, the examination may be completed by one more trial. The one we are going to mention is not necessary to the diagnosis, and only serves to corroborate the investigation.

Test III.—The *red* skein is presented to the subject. It is necessary to have a vivid red color, like the red flag used as a signal on railways. The color should be that of II. *b* of the plate, rather towards yellowish red.

Rule.—This test, which is applied only to those completely color-blind, should be continued until the person examined has placed beside the specimen all the skeins belonging to this shade, or the greater part, or else, separately, one of several colors of confusion (10—13). The red-blind then chooses, besides the red, green and brown shades, which (10—11), to the normal sense, seem darker than red. On the other hand, the green-blind selects opposite shades, which appear lighter than red (12—13).

Remark.—Every case of complete color-blindness discovered does not always make the precise mistakes we have just mentioned in the preceding examinations. These exceptions are either instances of persons with a comparatively inferior degree of complete color-blindness, or of color-blind persons who have been exercised in the colors of signals, and who endeavor not to be discovered; they therefore usually confound at least green and brown, but even this does not always happen.

Additional note.—We have not given rules for discovering *total* color-blindness, because we have not found any cases of this kind. If any such should be found, they will be recognized, according to the theory, by a confusion of every shade having the same intensity of light.

Violet-blindness will be recognized by a genuine confusion of purple, red, and orange in the second test. The diagnosis should be made with discrimination. The first test often shows blue to be a color of confusion; this may, in certain cases, be the sign of violet-blindness, but not always. We have not thought it advisable to admit defects of this kind, only the most marked cases, that other examinations establish as violet color-blindness, should be reckoned in the statistics. Finally, to acquire a desirable uniformity, it is necessary to add, that, in the preparatory examination, it is my habit to indicate in the journal, especially kept for that purpose, cases of *complete color-blindness* by 2 (2 R; 2 G; 2 V), those of incomplete blindness by 1, and those of feeble chromatic sense by 0.5 (0.5 R, 0.5 G; 0.5 V).